Uncertainties of Oxygen-NOx Effect from Predictive Model

By Jonathan Cohen, ICF International

Presentation at ARB Fuels Workshop

22 September, 2006

Topics

- Database is unrepresentative
- Oxygen-NOx Predictions for individual Tech 4 and Tech 5 Studies using 5 Models
  - Oxygen effects vary by model and study in size, direction, significance
- Tech 4 Dual normal and higher emitter models
  - Revised and improved
  - Fit the data statistically significantly better

PM Database is Not a Random Sample

Comparison of Test Fleet Tech 4 Normal and Higher Emitter Fractions with EMFAC 2000 Projections for 2005.						
Category	Obs	Obs	Vehi-cles	Vehi-cles	Emissions – Test Fleet	Emissions - EMFAC
	N	%	N	%	%	%
Normal (<1 g/mi)	3535	84	779	87	62	21
Higher	650	16	121	13	38	79
Total	4185	100	900	100	100	100

Statistical Models

- Latest PM database:
  - Tech 4 = 1986-1995
  - Tech 5 = 1996+, TOYOTA, AAMSUOXY
  - No outliers removed
  - Averages over repeated vehicle/fuel combinations
- Renormalize fuel parameters to mean = 0, SD = 1 for each Tech group

Statistical Models - Ctd

- Model 1. Main term OX + Other available terms. No interactions.
- Model 2. Main term OX + Other available terms. Interaction OXOX.
- Model 3. Main term OX + Other available terms. Interaction SUOX.
- Model 4. Main term OX + Other available terms. Interactions OXOX, SUOX.
- Model 5. New ARB Tech 4. All seven main terms. Interactions OXOX, SUOX, T5T5, SUSU, OLOL, ARAR, ARSU.
- Models 1-4: For each subset, OX + up to 6 more main terms arranged by fuel parameter CVs from highest to lowest. Use as many as possible where oxygen effect is estimable.

Tech 4 Studies

Study	Code	Study	Code	Study	Code
A/O-CURR	1	ARBETOH	13	EPA_ATL1	25
A/O-RVP/	2	ARBMSD96	14	EPA_ATL2	26
A/O-SULF	3	ARCO	15	EPA_PH3	27
A/O-TAME	4	ARCO5090	16	GMCONFRM	28
AO-HVT90	5	CHEVOX99	17	GMWSPA	29
AO-LOSLF	6	CHEVRON1	18	NIPER-P1	30
AO-SLFII	7	CHEVRON2	19	NIPER-P2	31
AOB17&18	8	CHEVRON3	20	UNOCAL	32
APIAROM	9	CHEVRON4	21	UNOCAL13	33
APIRVPOX	10	CHEVRON5	22	Tech 4	34
ARBATLOX	11	CHEVRON6	23	.	.
ARBATLP2	12	EPAEMFCT	24	.	.

Fig 1-1. Percent Changes in NOx as Oxygen Increases from 2 to 3.5 % for Tech 4 Studies
Subsets 1 to 14
Estimated Percent Change and a 95 % Confidence Interval
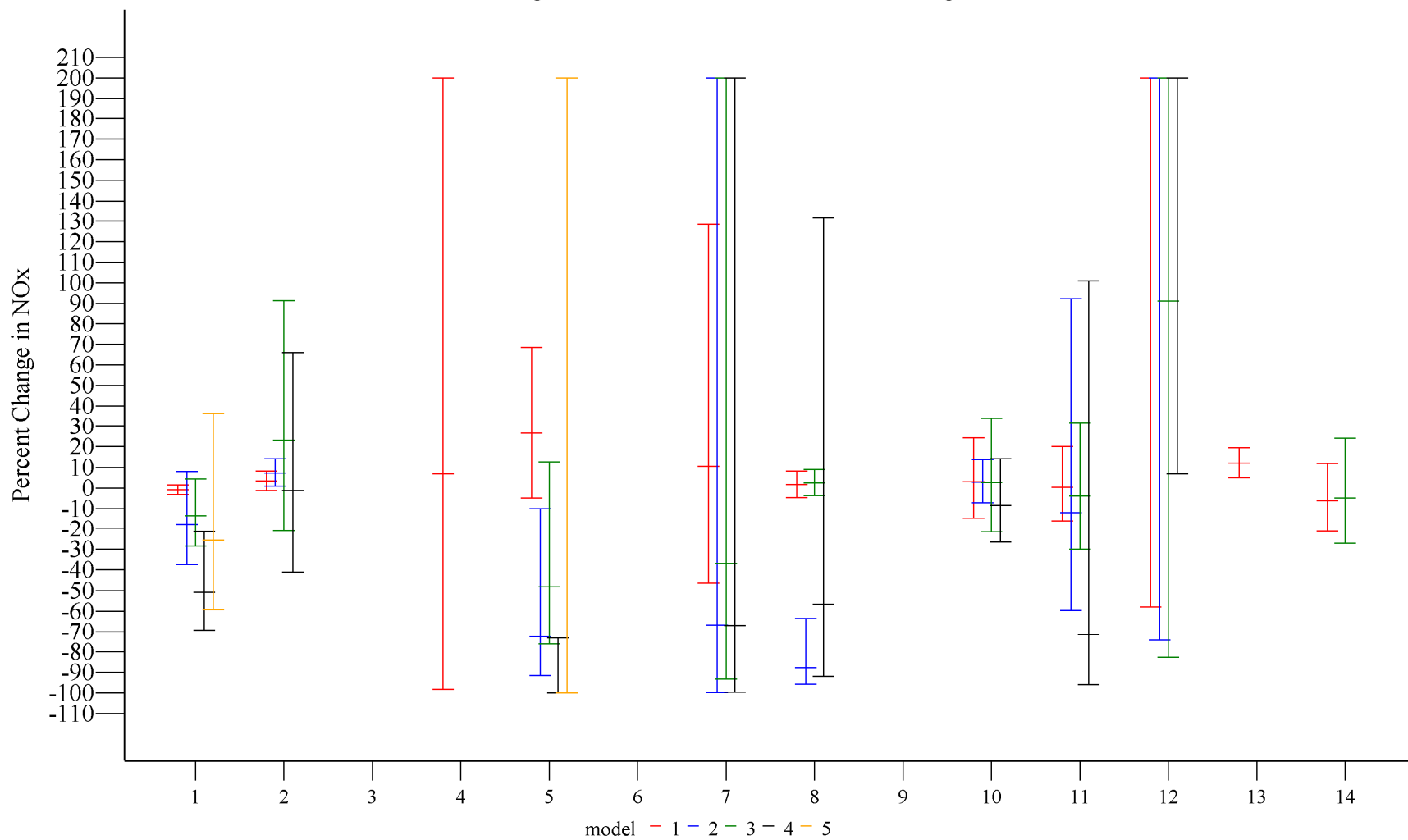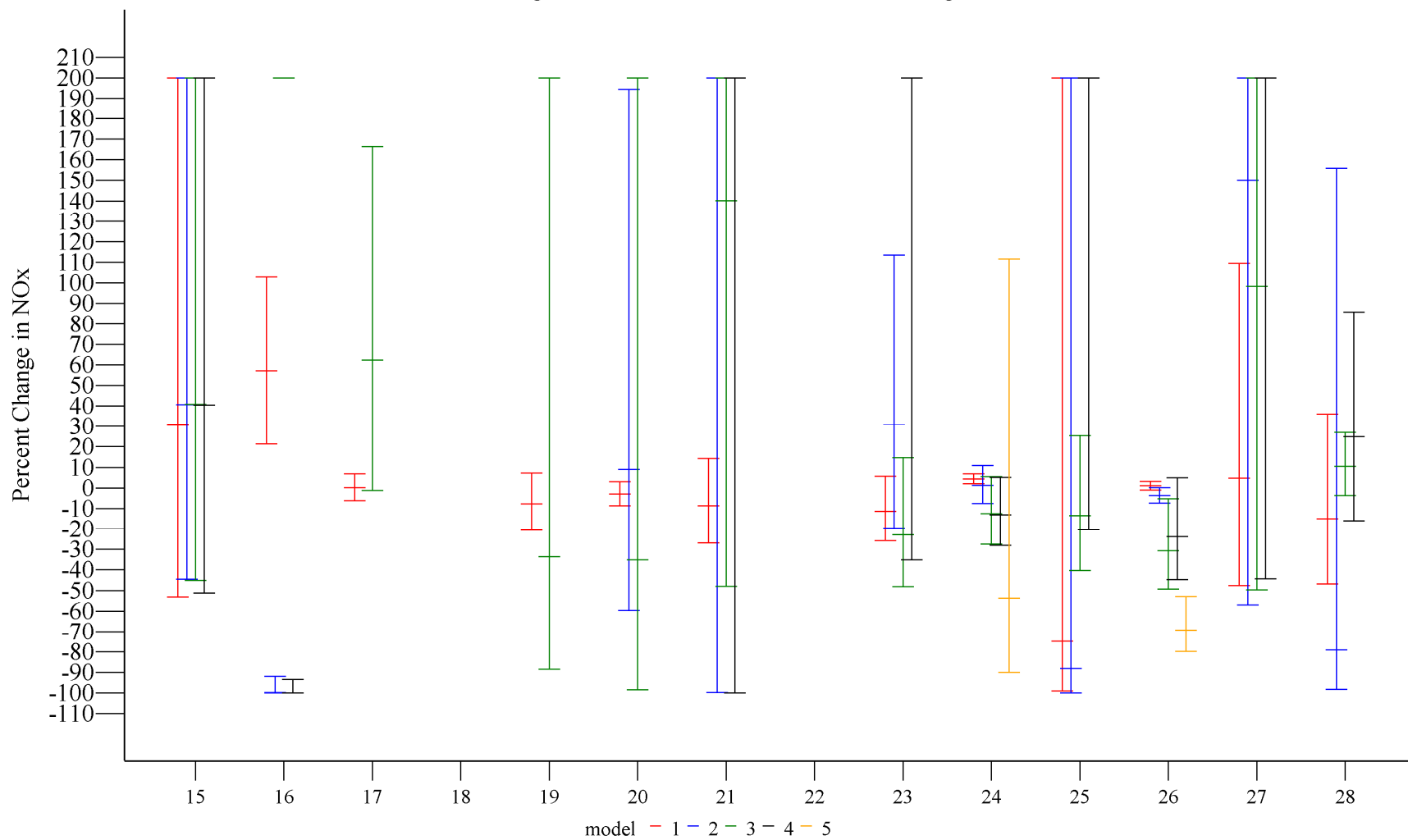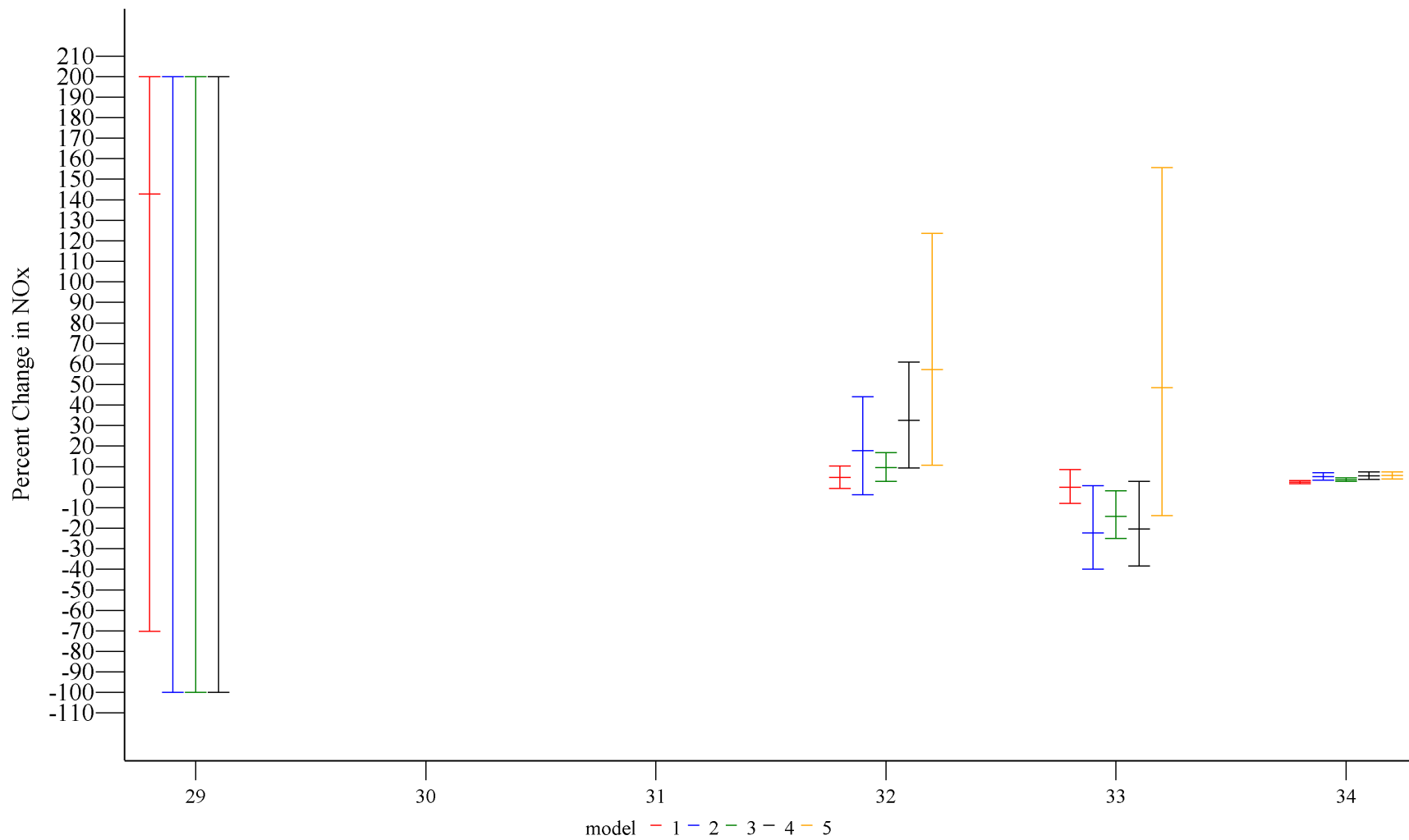Percentages Above 200 % Are Truncated to 200 for Plotting

Fig 1-2. Percent Changes in NOx as Oxygen Increases from 2 to 3.5 % for Tech 4 Studies
Subsets 15 to 28
Estimated Percent Change and a 95 % Confidence Interval
Percentages Above 200 % Are Truncated to 200 for Plotting

Fig 1-3. Percent Changes in NOx as Oxygen Increases from 2 to 3.5 % for Tech 4 Studies
Subsets 29 to 34
Estimated Percent Change and a 95 % Confidence Interval
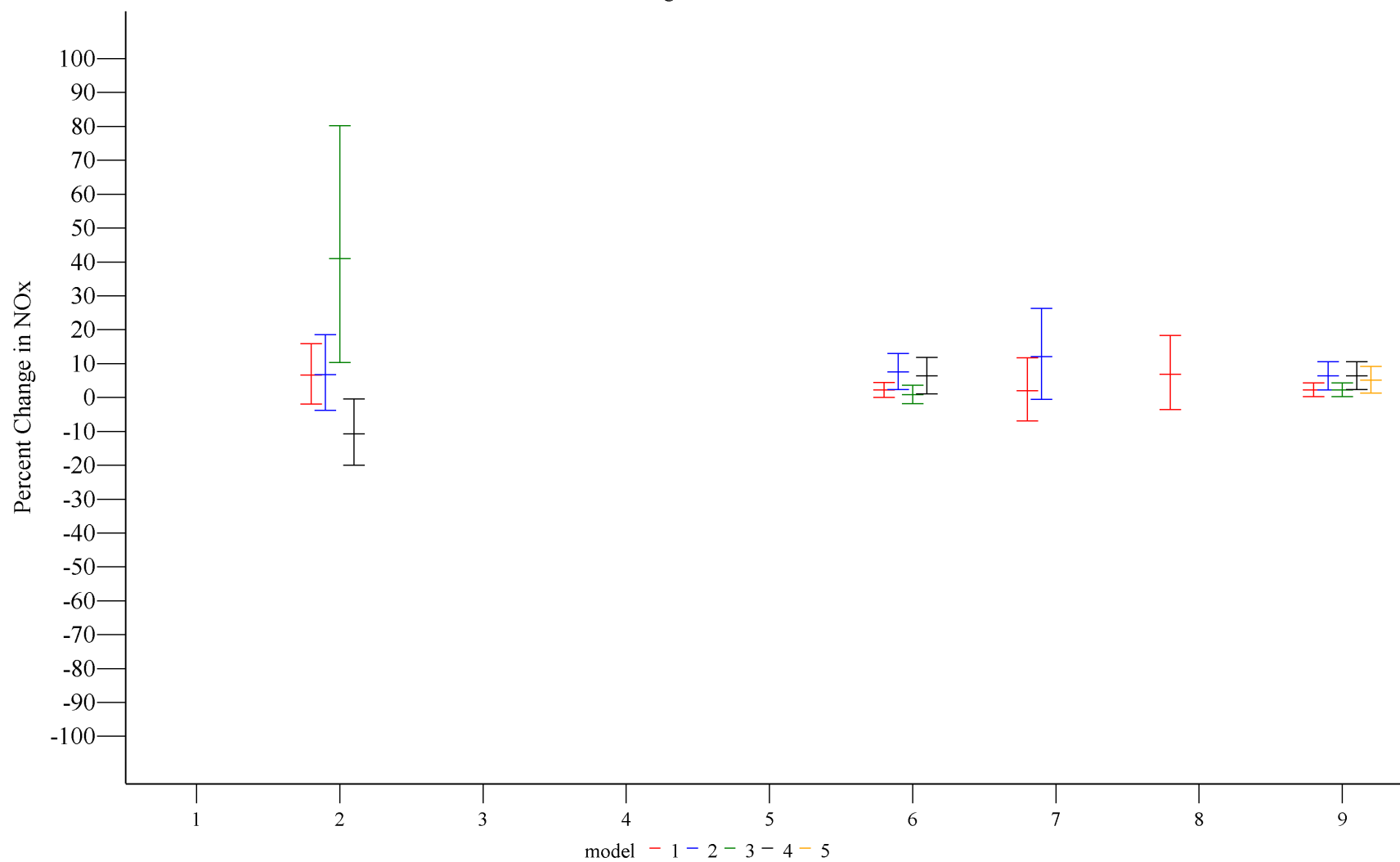Percentages Above 200 % Are Truncated to 200 for Plotting

Tech 5 Studies

| Study	Code
AAMALOSU	1
AAMSUOXY	2
CRCLOSUL	3
CRCLOSUO	4
CRC_E60	5
CRC_E67	6
EXXONMOBIL	7
TOYOTA	8
Tech 5	9

Fig 2. Percent Changes in NOx as Oxygen Increases from 2 to 3.5 % for Tech 5 Studies
Subsets 1 to 9
Estimated Percent Change and a 95 % Confidence Interval

Percentage Changes in NOx as Oxygen Increases from 2 to 3.5 % for Tech 4 and Tech 5 Models

Estimated Percent Change and a 95 % Confidence Interval

model   — 1   — 2   — 3   — 4   — 5
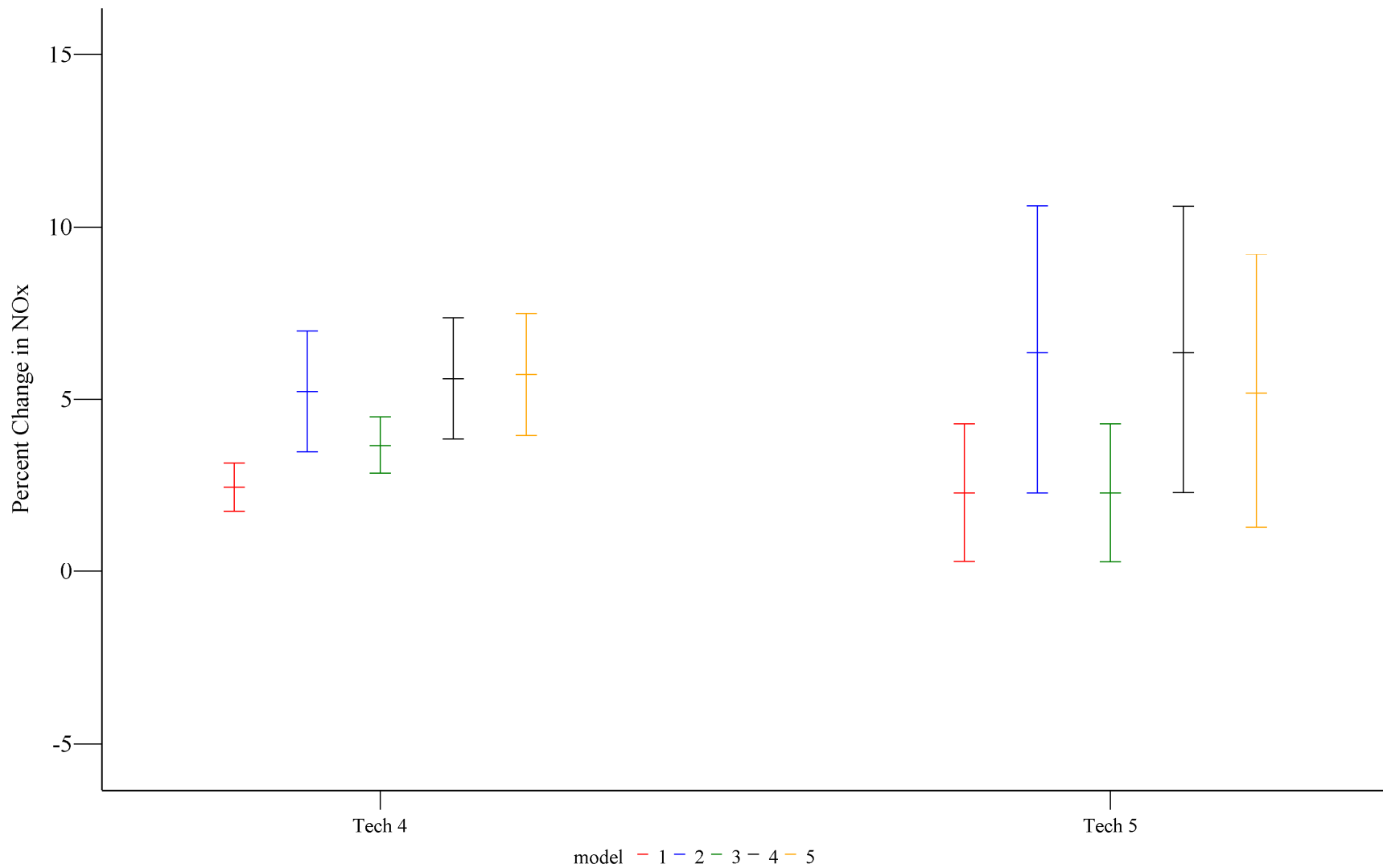
Summary 1

- Database is not a random sample
- Higher-emitting vehicles under-represented
- Oxygen effects are inconsistent across studies, varying in direction and statistical significance
- Oxygen effects vary across models
- Predictive Model ignores uncertainties in database, model formulation, and model coefficients in determining compliance: Uses a point estimate from one model

Tech 4 Dual Models: Higher and Normal Emitters

- For each Tech 4 vehicle, find emissions on closest fuel to Auto/Oil Fuel A:

  "Distance" = $\{RVP(F) - RVP(A)\}^2 / Var(RVP) +$

  $\{SU(F) - SU(A)\}^2 / Var(SU) + \ldots$

- Fuel A = most frequent base fuel in Tech 4
- Previous approach was to average emissions, potentially biasing "higher" emitters towards higher emitting fuels
- d = 0:   Only use 86 vehicles tested on A.
- d = 5:   Distance <= 5. 248 vehicles.
- d = 25:   Distance <= 25. All 900 vehicles.

Tech 4 Dual Models: Cutoffs

- Vehicle NOx emissions (closest fuel):

  <= Cutoff   "Normal"

  >   Cutoff   "Higher"

- Cutoff = 100 %, 60 % or 40 % of 1 g/mile NOx std

- 100 %: Higher = EMFAC Moderate, High, Very High, Super

- 60 %, 40 %: Gave two best-fitting models in previous analyses.

Tech 4 Dual Models: Codes

Study	Code	Study	Code
Normal, d=0, cutoff=100	1	Normal, d=5, cutoff=40	11
Higher, d=0, cutoff=100	2	Higher, d=5, cutoff=40	12
Normal, d=0, cutoff=60	3	Normal, d=25, cutoff=100	13
Higher, d=0, cutoff=60	4	Higher, d=25, cutoff=100	14
Normal, d=0, cutoff=40	5	Normal, d=25, cutoff=60	15
Higher, d=0, cutoff=40	6	Higher, d=25, cutoff=60	16
Normal, d=5, cutoff=100	7	Normal, d=25, cutoff=40	17
Higher, d=5, cutoff=100	8	Higher, d=25, cutoff=40	18
Normal, d=5, cutoff=60	9	Tech 4	19
Higher, d=5, cutoff=60	10	.	.

Fig 3-1. Percent Changes in NOx as Oxygen Increases from 2 to 3.5 % for Tech 4 Normal and Higher Emitters

Subsets 1 to 10

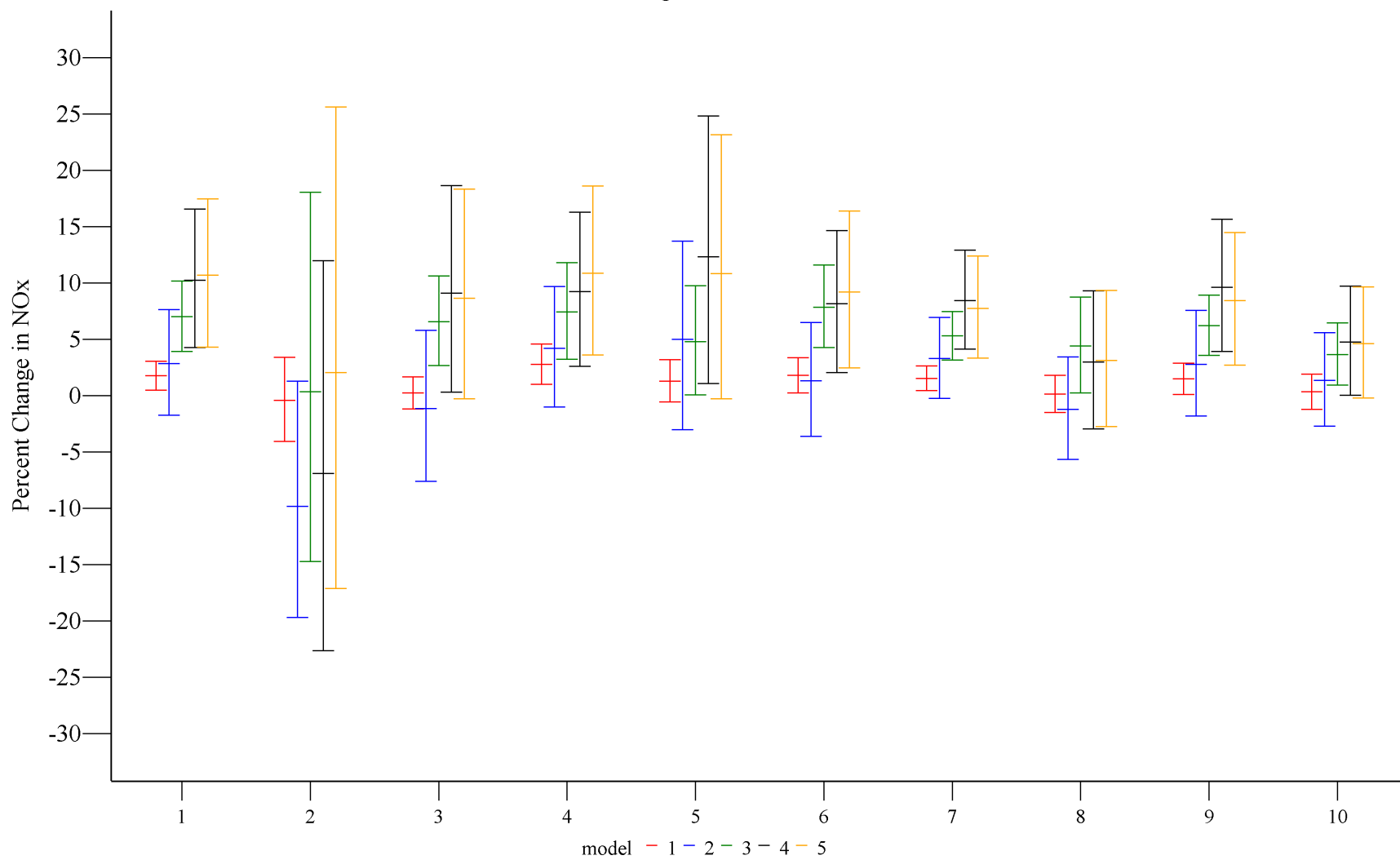Estimated Percent Change and a 95 % Confidence Interval

Fig 3-2. Percent Changes in NOx as Oxygen Increases from 2 to 3.5 % for Tech 4 Normal and Higher Emitters

Subsets 11 to 19

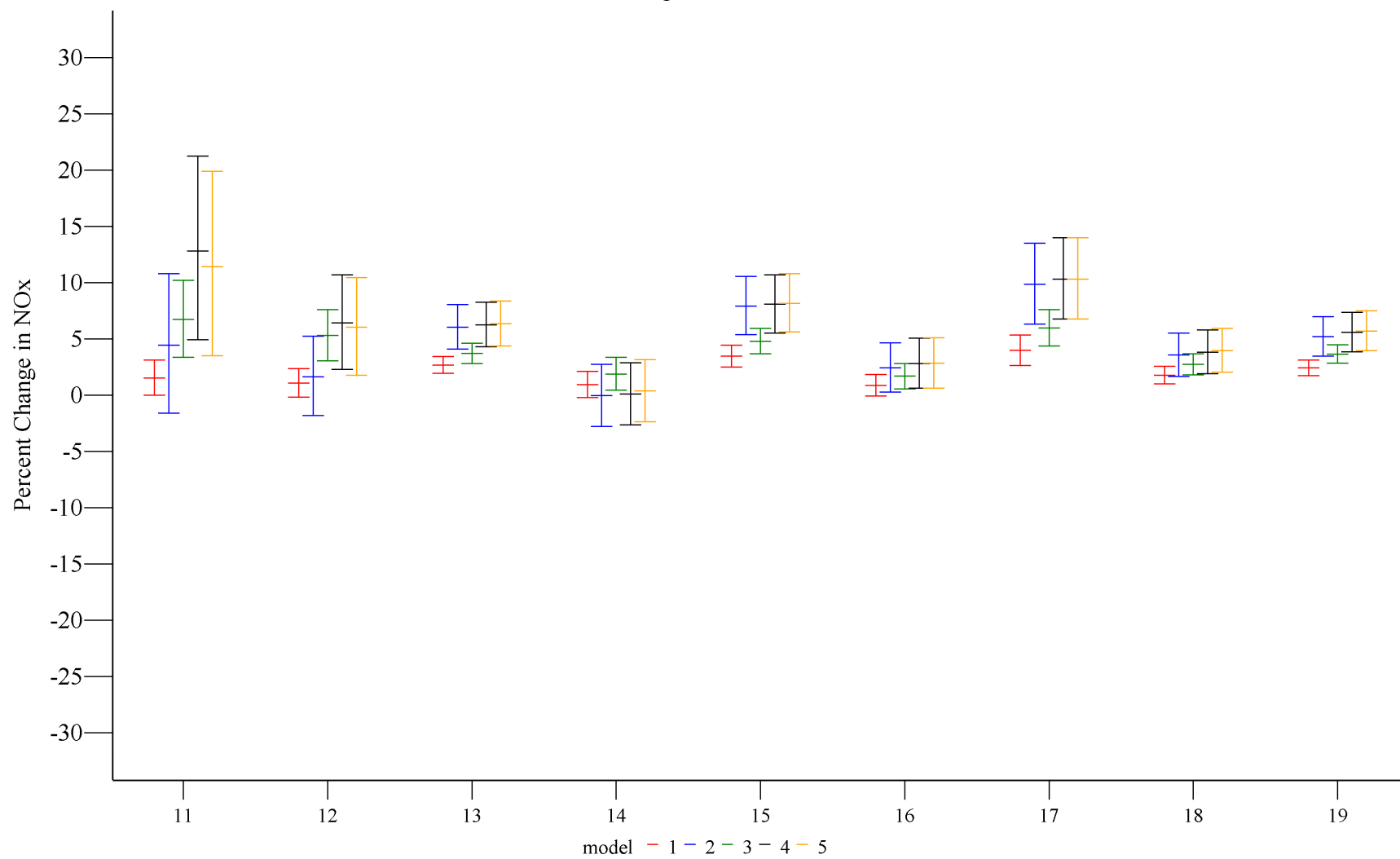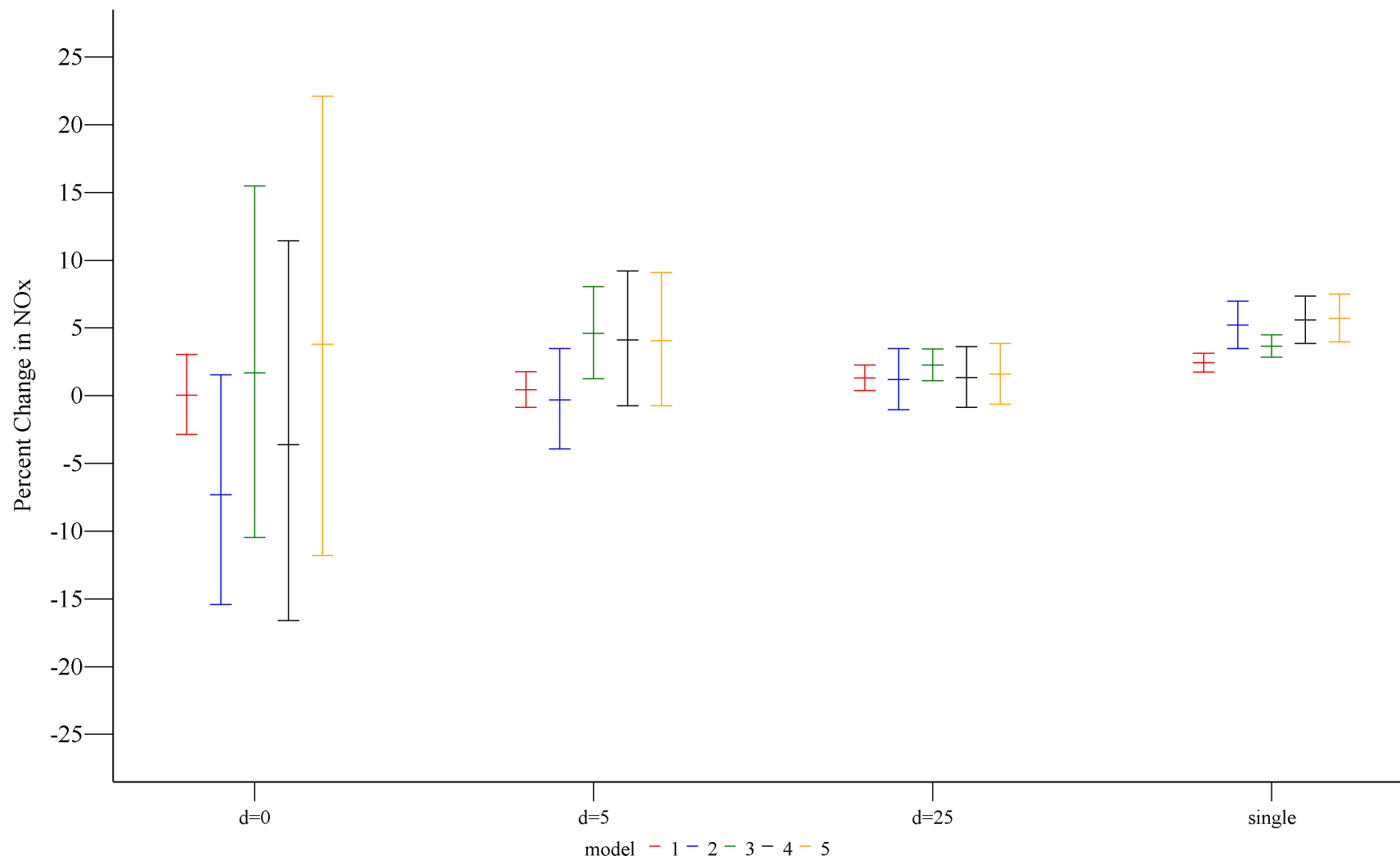Estimated Percent Change and a 95 % Confidence Interval

Fig 4. Weighted Averages for Dual and Single Models for 2005 based on EMFAC 2000
Dual Model Cutoff = 1 g/mile
Estimated Percent Change and a 95 % Confidence Interval

Summary 2

- Dual models fit the data statistically significantly better
- Best-fitting of three cutpoints was 60 %
- Higher emitters respond less to oxygen than normal emitters
- Ideal model would have multiple or infinitely many cutpoints – dual model is an approximation
- Possible "engineering" explanation: catalyst aging; fresher catalysts are less stable